The following spring, they sealed the upper vents and left the weep holes at the base of the wall to allow drainage. Measurements showed the moisture content of the wood quickly rose to over 20% — the threshold at which mold will start growing. Liquid water was pooled at the base of the wall, and the interior poly was covered with a film of condensation. The researchers concluded that a vented airspace can control most interior summer condensation by removing it before it gets into the wall system.

If you can't guarantee ventilation (which is the case in many poorly detailed brick and stucco exteriors), Straube recommends installing an outboard layer of low-permeance sheathing. Field testing, computer modeling, and simple hand analysis all confirm that walls with extruded polystyrene (XPS) sheathing have sufficient outboard vapor resistance to control inward vapor drives in almost all situations. And if moisture condenses between the housewrap and the sheathing (as can happen after sundown when the temperature drops), XPS doesn't rot.

By the way, Straube recommends keeping the housewrap as a barrier against liquid water and exfiltration, but concedes that it may not work as well as advertised. A number of studies have noted that housewraps can lose their waterproof nature when contaminated with surfactants. These are present not only in soap, but in the saps and oils of some woods. The answer is to keep surfactants away from the housewrap. A precaution is to mount the siding on furring strips and to prime the furring and the siding.

Lighten Up

Another often-overlooked factor in inward vapor drives is the color of the siding. Since dark siding absorbs more solar energy than light siding, a dark-colored home will be more likely to have problems with inward vapor drives. "Dark-colored EIFS will have more problems than light-colored EIFS," he says. "Sometimes that can be the difference between success and failure."

Straube has teamed up with John Timusk at Trow Consulting Engineers in Brampton, Ontario, to write a guide showing designers and builders how to cope with these problems. It will include findings from field research, anecdotal evidence, and sophisticated computer modeling. They expect to complete the guide early next year.

For more information, contact: John Straube, Civil Engineering Department, University of Waterloo, Engineering Group, 200 University Avenue, Waterloo, ON N2L 3G1, Canada; (519) 888-4567, ext. 2378, Fax: (519) 888-6197, E-mail: jfstraub@uwaterloo.ca, Web site: sunburn.uwaterloo.ca/beg.

Insulation Type Has Little Effect on Air Infiltration

A recently completed field study by Dr. Gren Yuill, professor of architectural engineering at Penn State University, finds that there is no significant difference between fiberglass insulation and wet-blown cellulose when it comes to blocking air infiltration through walls.

The study also finds that three popular air-sealing methods used to reduce infiltration work about equally well.

In the research, funded by the North American Insulation Manufacturers Association (NAIMA) and Owens Corning, Yuill used two full-sized test houses (both 1,361 square feet) located at the Owens Corning Technical Center in Granville, Ohio.

The houses, which are nominally identical, include 2x4 framing, fiberboard sheathing (untaped), and aluminum siding, representing "average" construction quality. The houses have full basements, functioning forced-air heating systems (with electric furnaces), and mock plumbing to simulate roof penetrations and insulation compression. No vapor barriers were in place during the tests and neither of the houses was caulked or sealed.

Yuill and his team were able to isolate and measure the amount of air leaking through the walls, floor, ceiling, windows and doors, and ductwork (see Table 1). They ran each of the blower door tests at least twice,

Table 1 — Distribution of House Leakage (CFM at 30 Pascals)

Component	Condition of wall	House B	Percentage of Total
Exterior wall	Empty cavity	1,315	
Exterior wall	Fiberglass insulation only	687	
Exterior wall	Fiberglass insulation plus drywall	154	14%
Floor	Fiberglass insulation plus drywall	387	36%
Partitions plus ceiling	Fiberglass insulation plus drywall	442	40%
Doors plus windows	Fiberglass insulation plus drywall	106	10%
House above floor	Fiberglass insulation plus drywall	702	
Whole house	Fiberglass insulation plus drywall	1,089	100%

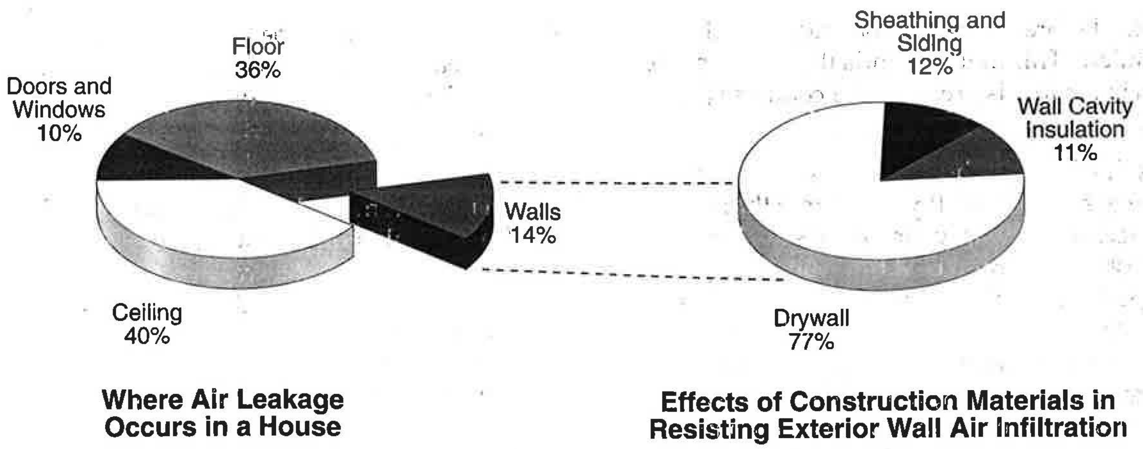

Figure 1 — How walls and wall components affect air infiltration in houses.

and some as many as ten times, to verify the results and draw comparisons. The tests consistently occurred under low-wind conditions, often at night.

Yuill found that only 14% of the total air infiltration came through the walls, compared to 40% and 36%, respectively, through the ceiling and floor (see Figure 1). "One message that's in these numbers," he says, "is that while it's still important for a builder to incorporate air-tightening techniques in the wall system, the floor and ceiling should receive most of the attention."

Yuill performed numerous additional tests to study the leakage characteristics of the walls. By using the empty-cavity (no drywall or insulation) infiltration measurement as a base and methodically changing the walls' components for each subsequent test, he determined the airflow resistance of the individual components (see Figure 1). To make the changes easier, the drywall was screwed in place and sealed with duct tape for each test instead of being nailed, taped, and spackled.

"We discovered that the drywall is by far and away the most important barrier to air leakage in this type of wall, contributing 77% of the total airflow resistance, with sheathing and insulation running a distant second and third," says Yuill. He notes that drywall's role as an air barrier probably wouldn't be as pronounced in walls employing different construction (e.g., taped foam sheathing).

One of the most interesting parts of the study was the investigation of how different types of insulation affect the air tightness of houses. The first test measured infiltration through the walls with inset-stapled R-13 kraft-faced fiberglass batts in the cavity. Yuill removed the drywall and replaced the fiberglass with wet-blown cellulose, which he allowed to dry for 53 days. With the drywall back in place and retaped, he repeated the blower door tests.

As shown in Table 2, the results can be interpreted in two ways. One interpretation is based on the average airflow through the empty wall cavity before and after the test. Using this method, the average reduction in airflow through the wall was greater with fiberglass (by 52 CFM) than with wet-blown cellulose.

The other method bases the reduction only on the measurement of airflow through the empty

Table 2 — Air Flow Measured Through Fiberglass and Cellulose (CFM at 30 Pascals)

House	Insulation	Empty cavity (no insulation or drywall)			Drywall plus insulation installed	Reduction compared to:	
		Pretest	Post-test	Average		Pretest	Average
B	Fiberglass	2,199	2,298	2,249	1,089	1,110	1,160
B	Cellulose	2,298	1,921	2,110	1,049	1,249	1,061
B	Difference (fiberglass – cellulose)					-139	99
C	Fiberglass	2,029	1,875	1,952	1,203	826	749
C	Cellulose	1,875	1,739	1,807	1,063	812	744
C	Difference (fiberglass – cellulose)					14	5
Average difference (fiberglass – cellulose)						-63	52

cavity taken before the insulation and drywall were installed. This method finds that the average reduction in airflow is greater with cellulose (by 63 CFM).

Yuill says that both methods have merit, depending upon your assumptions. If you assume that the measured changes in the empty air cavity's airflow (pretest vs. post-test) are the results of the random effects of workers performing the renovations or random experimental errors, then it's more logical to use the average airflow method. If, on the other hand, you assume that the air tightness of the cavity has been somehow influenced by the insulation just removed (e.g., small cracks in the sheathing were sealed with bits of insulation or the framing swelled due to increased moisture) then it's more logical to compare airflows using the single, empty-cavity measurement taken before the insulation and drywall were installed.

Yuill tells *EDU* that it's impossible to know which assumption is more realistic and therefore impossible to conclude which of the two insulation materials provides the more airtight house. But one thing is clear: the difference is insignificant.

Though the actual air permeability of wet-blown cellulose is much lower than fiberglass, Yuill's findings suggest that both are so permeable compared to the other components in the wall — especially the drywall — that it doesn't make much difference. And when you consider that walls play a relatively minor role in the house's overall infiltration rate — compared to floors and ceilings — the difference becomes even less important.

"Even if you removed the insulation completely, you're only talking about a 1.5% increase in air leakage for the house overall," says Yuill. "Or, to put it another way, small differences in workmanship in a house are likely to be more significant than the differences in the air permeability of the wall insulation." (See "Does Insulation Choice Really Affect Infiltration?", *EDU*, July 1997.)

Yuill's study also compared the air tightness of fiberglass batts to that of blown fiberglass (commonly referred to as blown-in-blanket, or BIB). While the batts proved to be 12% more resistant to air infiltration than BIB, the difference — in terms of the home's total air infiltration — would be an insignificant 0.2%.

It's important to note, however, that adding wall insulation could have a much more pronounced effect in stopping air infiltration in some retrofit applications (e.g., older houses with balloon construction) where the wall is open, for example, to a crawlspace or attic, forming a bypass. Wall insulation might also play a more significant role in houses built on slabs, where neither a basement nor crawlspace is contributing to the home's overall infiltration rate.

Blower Doors: Better Than We Thought

While the tests conducted at the Owens Corning Technical Center were designed to study infiltration, they coincidentally provided reams of useful data on the accuracy of blower doors.

The Penn State research team, lead by Dr. Gren Yuill, ran hundreds of air infiltration tests over the course of the project, using both a conventional, manual-type blower door (Infiltec Model E-3) and a state-of-the-art computer-controlled model (Minneapolis Blower Door Model 3 with an APT [automated performance testing] controller).

"Over the course of the research we found the manual-type blower door to be quite accurate," says Yuill. "Over hundreds of tests, the standard deviation was only 1%, which is much more accurate than people thought possible."

Yuill also has high praise for the APT system, which he says reduced his average test time by about one-third with a standard deviation of only .4%. (He plans to report these findings in detail at the ASHRAE Thermal VII meeting next year.)

"In most situations where you're using a blower door, travel time and set-up time are the big factors, because you're always moving from one house to the next," explains Yuill. "But in our case, where we ran hundreds of blower door tests on the same house, the test time became the most significant factor. And the APT saved us about 10 minutes per test."

Though The Energy Conservatory, maker of the APT, first announced the system almost two years ago (see ***EDU***, January 1996), company president Gary Nelson says it's only now becoming commercially available (see Figure 2).

The APT is both an automated control system for blower doors and duct testers and a sophisticated data logger, with two pressure channels standard (up to eight optional) and inputs for up to eight other sensors to measure temperature, relative humidity, carbon monoxide, carbon dioxide, etc.

For more information, contact: The Energy Conservatory, 5158 Bloomington Avenue South, Minneapolis, MN 55417; (612) 827-1117, Fax: (612) 827-1051, E-mail: energy@isd.net.

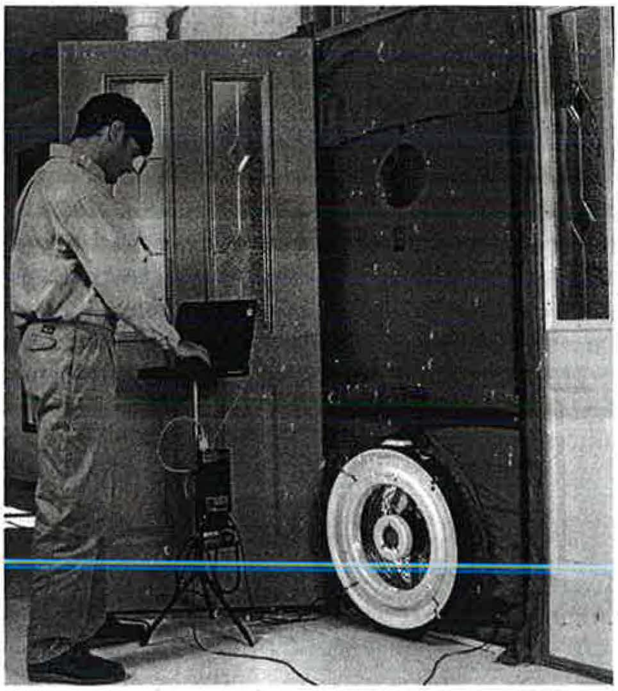

Figure 2 — An APT-2 and blower door.

The final phase of Yuill's study considered the efficacy of materials and techniques used to tighten houses. He applied four methods to the test houses and evaluated them with blower door tests:

1. Housewrap over fiberboard sheathing;
2. Taped rigid foam sheathing;
3. Comprehensive caulking and sealing; and
4. Housewrap over untaped rigid foam sheathing.

The study found that methods 1, 2, and 3 work equally well, reducing whole-house infiltration by about 9%. Using housewrap over untaped foam produced a 12% reduction, but would be more costly than the other alternatives.

Blower door tests on untaped rigid foam sheathing and untaped fiberboard showed that they had very little resistance to air infiltration.

For more information, contact: Dr. Gren Yuill, Department of Architectural Engineering, 216 Engineering A, University Park, PA 16802; (814) 863-2090, Fax: (814) 863-4789, E-mail: gkyarc@engr.psu.edu.

Pulte Homes, Other Builders Adopt Vent-Free Attics

The thought of building a new house without any attic ventilation would be more than counterintuitive to most designers and builders. It would be heresy.

Yet that's exactly what Pulte Homes and Watt Homes — two large production builders — are doing in their new subdivisions in Las Vegas, Nevada.

Pulte Homes of Las Vegas, a division of Pulte Homes Corp. of Bloomfield Hills, Michigan, the largest homebuilder in the US, will use vent-free attics on 90 new homes in its new Cypress Pointe subdivision.

The design, which places fiberglass insulation up flush against the roof decking rather than on the floor of the attic, turns the attic into a conditioned space, eliminating all soffit, ridge, and gable vents. While this increases the area that has to be heated and cooled, it compensates by eliminating duct losses.

Pulte tested the vent-free attic in two prototype houses that were designed by the Building Science Consortium, one of several R&D consortiums operating under the US Department of Energy's Building America Initiative.

David Beck, Pulte's director of construction, tells *EDU* that the prototypes performed so well — saving 30% on energy consumption — that Pulte decided to adopt most of the design modifications in the new houses at Cypress Pointe. In addition to using vent-free attics, Pulte will:

- Upgrade the windows from aluminum frame, dual-pane clear glass to vinyl windows glazed with PPG Sungate 1000 (see *EDU*, October 1997);
- Downsize the central air conditioner from five tons to four; and
- Eliminate the furnace in favor of a combo heating system, which links a high-capacity water heater in the garage to an air handler in the attic. (Pulte had previously placed a furnace in the attic, which isn't feasible with vent-free attics.)

Beck says that eliminating soffit, ridge, and gable vents saves Pulte about $500 a house and enables the stucco contractor to run stucco right up the wall and out over the soffit, creating a very tight and attractive wall. However, the upgrade in glazing, the unconventional insulation work, and the new ventilation system (see below) add costs, so the total price per house currently nets out about $150 higher. (The houses in Cypress Pointe will range from 1,700 to 2,260 square feet and be priced from $150,000 to $170,000.)

"When you're trying something new, the contractors want to charge a little more at first, till they learn the system," says Beck. "But eventually we're going to build these houses for zero additional cost."

Why Go Vent-Free?

Joe Lstiburek, head of Building Science Corporation of Westford, Massachusetts, and lead designer of the Pulte prototypes, says that turning the attic into a conditioned space inflicts a 3%-5% penalty in increased heating and cooling costs, but eliminates the 20%-30% loss that typically stems from leaky ductwork.

"Basically, I got tired of trying to convince HVAC contractors to install tight ductwork and tired of trying to convince builders to make space in their designs to install the ductwork inside the conditioned space," Lstiburek explains. "So I finally said, 'Hey, let's wrap the building *around* the ductwork' " (see Fgure 1).

The vent-free design also reduces whole-house air infiltration from between 1,500 and 1,700 CFM (at 50 pascals) to about 750 CFM, says Lstiburek. This, along with the high-performance glazing, makes it possible to downsize the air conditioning system.

However, since the modified house is substantially tighter than its predecessors, it requires controlled ventilation and outside air. This is delivered via a fresh air duct connected to the return side of the furnace, controlled by a FanRecycler (see *EDU*, September 1997).

Wrestling with the Insulation

The unfaced fiberglass batts (R-30) used in the Pulte prototypes were held in place by rows of wire fastened to the top chords of the roof trusses. While the method works, insulation contractors found it slower — and therefore more costly — than laying batt on the attic floor (see Figure 2).

"The wire-and-batt installation method is not an elegant solution, especially on complex roofs," Lstiburek admits. "So we're searching for a better way."

At least three different ideas have been tendered to make the insulation work easier. One of the most promising, says Shawn Gibson, regional sales manager for Gale Insulation, which did the insulation work on the Pulte prototypes, would be to use a fiberglass blown-in blanket (BIB) instead of batts. Gibson, who is meeting with technical representatives from Certainteed to study the idea, says that BIB, in additional to possibly saving time, results in a much cleaner looking installation than batts, and that looks are an important consideration to Pulte. "I know we can make it work," says Gibson. "The question is, can we make it work within Pulte's budget?"

Another option, according to Lstiburek, would be to use blown-in cellulose, in which the first six inches would be held in place by net and the last three layered on top. He says he's currently exploring the idea with representatives from Louisiana-Pacific.

Lastly, it might be feasible to use some type of sprayed-on foam insulation, such as Icynene, which Lstiburek used in an experimental house in Orlando, Florida.

Regardless of the approach, code issues — especially regarding flame spread on the insulation — will have to be resolved. And local code inspectors — accustomed to seeing insulation on the attic floor with plenty of vents in the space — are bound to have questions — if not qualms — when they find the

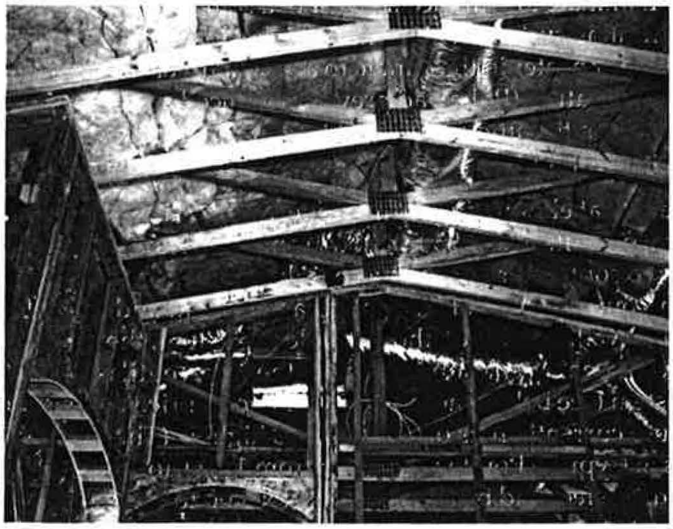

Figure 1 — Ductwork in conditioned space.

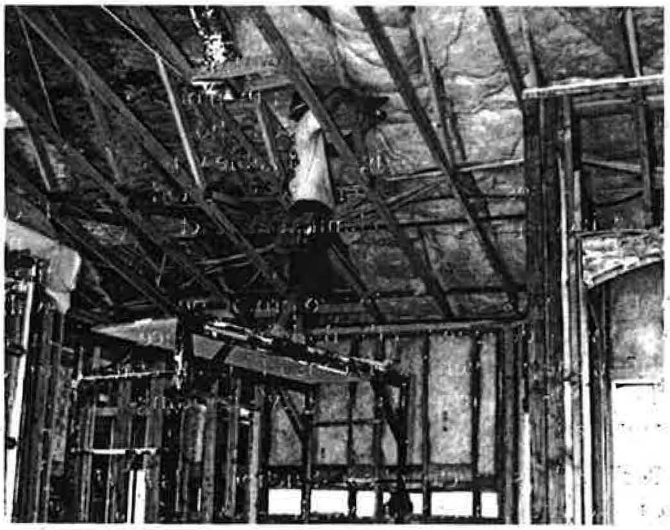

Figure 2 — Installation of fiberglass insulation tight to underside of roof deck..

insulation suspended overhead and no vents in sight. The fact that the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) does not require attic ventilation in its new 1997 *Handbook of Fundamentals* (see ***EDU***, October 1997) may be lost on building inspectors who have spent their entire careers looking at soffit, gable, and ridge vents.

Vent-free attics may also require some rethinking in how construction work is scheduled. "It would be an advantage, using this system, if we could insulate before the HVAC, electrical, and plumbing subcontractors go in," notes Gibson. He says it would also help to reroute electrical cables so they don't run along the eaves, which the insulation has to fill. Instead, the cables might be tied off to and run along the roof trusses. For similar reasons, he says it'd be advantageous to locate plumbing stacks tight to the trusses, so the insulation contractor wouldn't have to cut in around them.

Such details notwithstanding, vent-free attics seem to have a promising future in warm climates. In addition to Pulte and Watt Homes in Las Vegas, Lstiburek says that production builders in Tucson, Houston, and Orlando are considering their use.

For more information, contact: Joe Lstiburek, Building Science Corporation, 70 Main Street, Westford, MA 01886; (978) 589-5100, Fax: (978) 589-5103.

Sandbag Wall System Shows Promise

A US Department of Energy engineer has developed a unique wall system that he says can use natural, manufactured, or waste material as insulation for less cost than a conventional wall. Builders can use it to insulate existing houses or to construct new walls. If it proves commercially viable, the system should appeal to both energy advocates and environmentalists. And while aimed at builders of low-income housing, the system could eventually gain a mainstream niche in certain parts of the country.

Arun Vohra describes his "Vohra Wall" as a "low-cost, sustainable insulated wall construction technology." His idea is to fill sandbags with an insulating material, and stack them against the outside of an existing building or use them as infill in a post-frame structure.

Figure 1 — The wall of this 67-year-old adobe home was covered with pumice-filled sandbags stacked between 4x4 corner posts. The bags were secured with plastic ties.

He first demonstrated the system two years ago on a 67-year-old adobe house in New Mexico (see Figures 1-3). Vohra installed 4x4 posts at the exterior corners of one wall of the house, then wrapped a three-foot-wide and six-inch-thick layer of crushed stone in polypropylene felt and placed it on grade between the posts to act as a subbase. He stacked sandbags between the posts, and looped plastic straps around every other sandbag. Vohra then stretched a wire mesh across the face of the bags, tied it to the straps, and covered it with stucco.

The most important benefits of this design, says Vohra, are versatility, simplicity of construction, and low cost. Because it's self-supporting, the system adds no additional structural loads to the house. It requires no foundation and needs only a small amount of lumber. The materials used are readily available, and construction does not require expensive machinery or specialized skills.

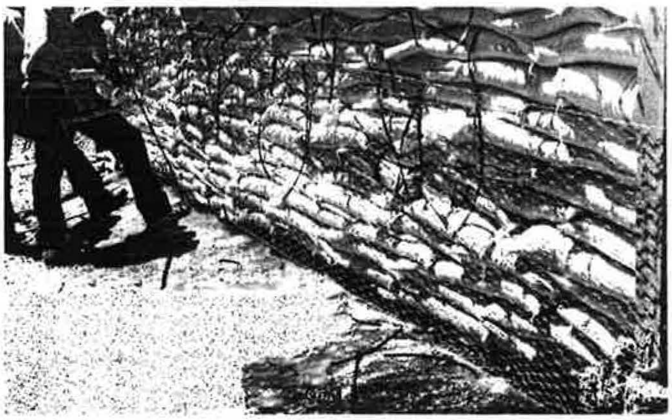

Figure 2 — Wire netting was stretched across the corner posts, tied to the plastic straps, and covered with stucco.